FCC Hearing

Albuquerque, NM
January 19,1998

Overcoming Obstacles to Telephone Service for Indians on Reservations

Industry Viewpoint:

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Contents

Background
ArrayComm

- Founded in 1992; Headquartered in San Jose, California
- Develops, supplies and licenses wireless local loop infrastructure and subscriber equipment
- Develops and and licenses smart antenna technology/software for cellular, cordless and wireless local loop (WLL) systems
- Systems deployed in Asia, Latin America, Middle East and Europe

Background

Why is cellular is not competitive here?

- Federal regulatory policies have helped incumbents
  - Telephone monopolies were granted broad cellular licenses
  - Subsequent cellular/PCS spectrum was fragmented
  - PCS auctions were cost prohibitive for many challengers
  - It is more costly for new players to deploy at PCS frequencies
  - Paired frequency allocations perpetuated the dominance of old mobile standards and large incumbent providers
- Built-in ILEC cellular market advantage
  - Wireline monopoly position helped fund cellular
  - Cellular duopoly saw no formidable competition
  - Controls or controlled by major suppliers
  - Control of cumbersome standards-setting process

Background

Why hasn't WLL technology taken off yet?

- Technology, marketing and implementation
  - WLL history has been marked by costly and inefficient cellular systems, relabeled as WLL and ushered in by incumbent suppliers
  - Poor early performance resulted in lingering image problems
  - Highly-competitive technologies have entered the market…
  - …but PSTN interconnection (switch interface) barriers have been erected by suppliers of PSTN switching gear
- Populous, developing countries were expected to help drive the economies of scale, but exhibited…
  - Economic turndown has postponed global ramp-up
  - Poor radio regulation and spectrum planning/availability
  - Import tariff barriers/unrealistic local content goals
  - Future economic driver will be Internet access

Wireless Telephony Alternatives

Wireless Coverage Models

- Satellite
- Mobile Cellular/PCS
- Pedestrian Cordless
- Wireless Local Loop
- Microwave

Widest

Most selective

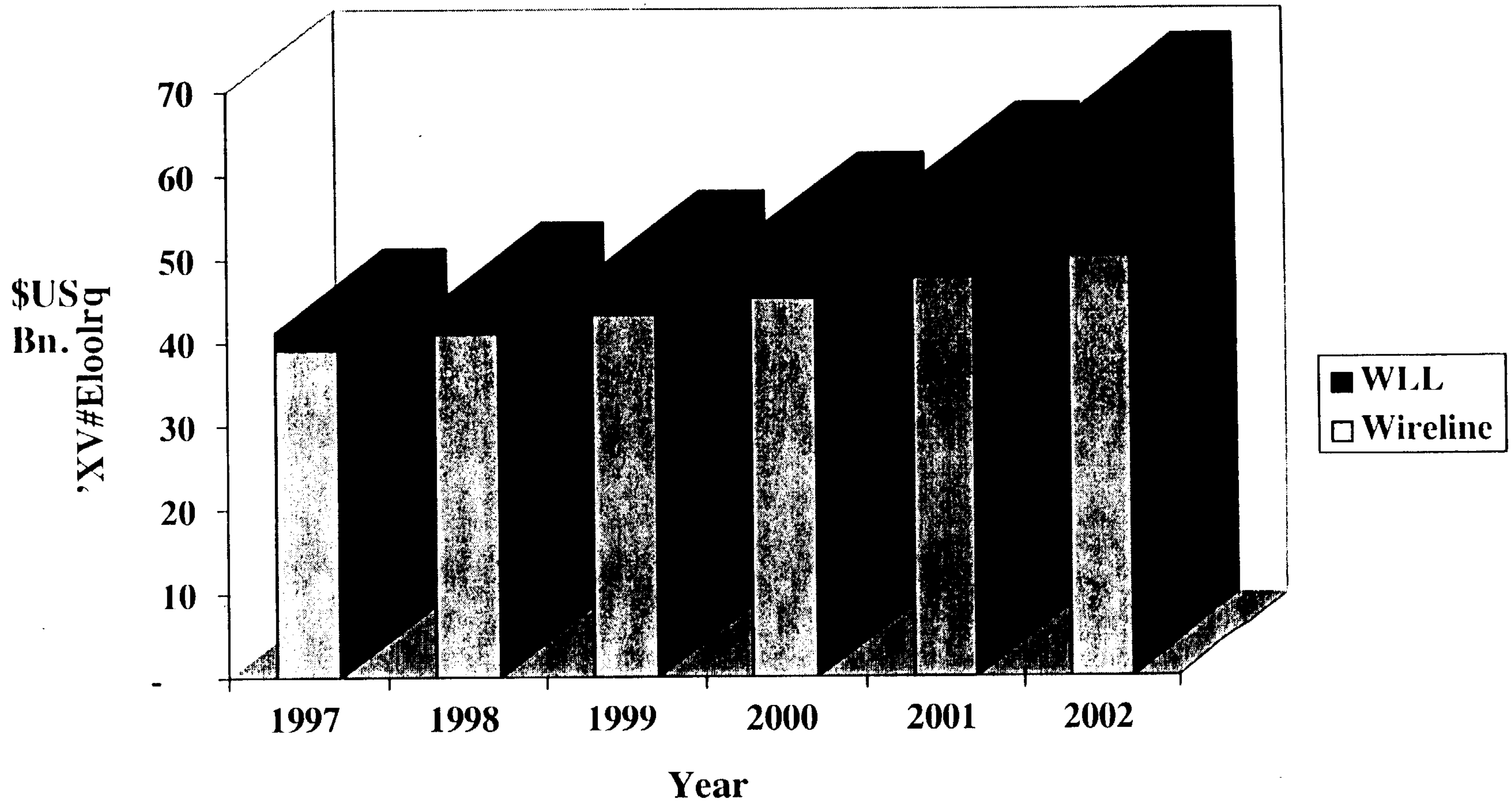
Most Expensive

Most Efficient

Price Boundaries for Individual User Access

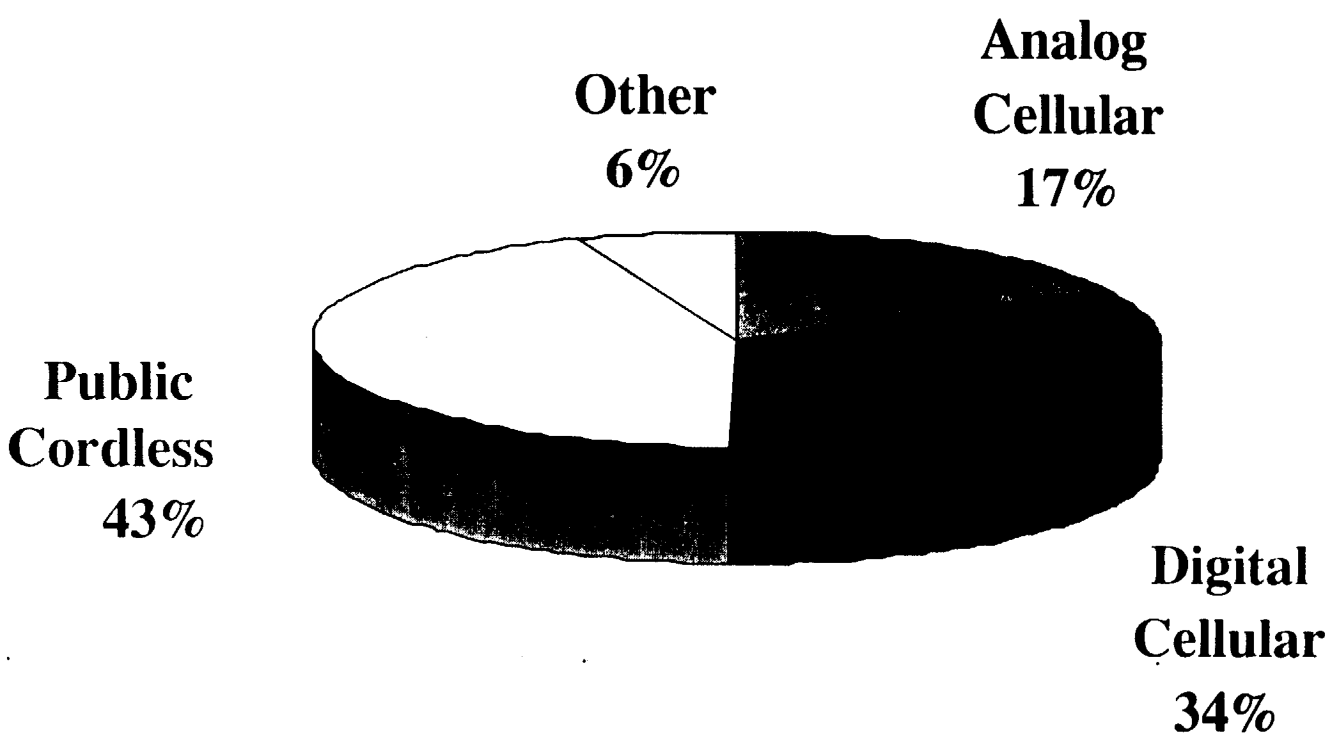
Wireless Telephony Alternatives

Wireless Local Loop Infrastructure Spending Worldwide



Sources: Allied Business Intelligence, OMSYC, ArrayComm
Note: 1997 average project size was <US$5M

Wireless Telephony Alternatives
Wireless Local Loop Market Segmentation*



*Based on an ArrayComm research and analysis of 366 WLL projects worldwide.

Sources: ArrayComm research, Advanced Cordless Communications, Business Wire, CommunicationsNow, FCC, ITC, tele.com, Telecom.Development, Yankee Group

Wireless Telephony Alternatives
Select Fixed Wireless Technologies

- Specialized Solutions
  - Microwave
  - Satellite
  - Terrestrial rural systems
- Mass Market Technologies
  - Fixed Cellular
  - Fixed Cordless
  - True WLL (proprietary systems, enhanced cordless)

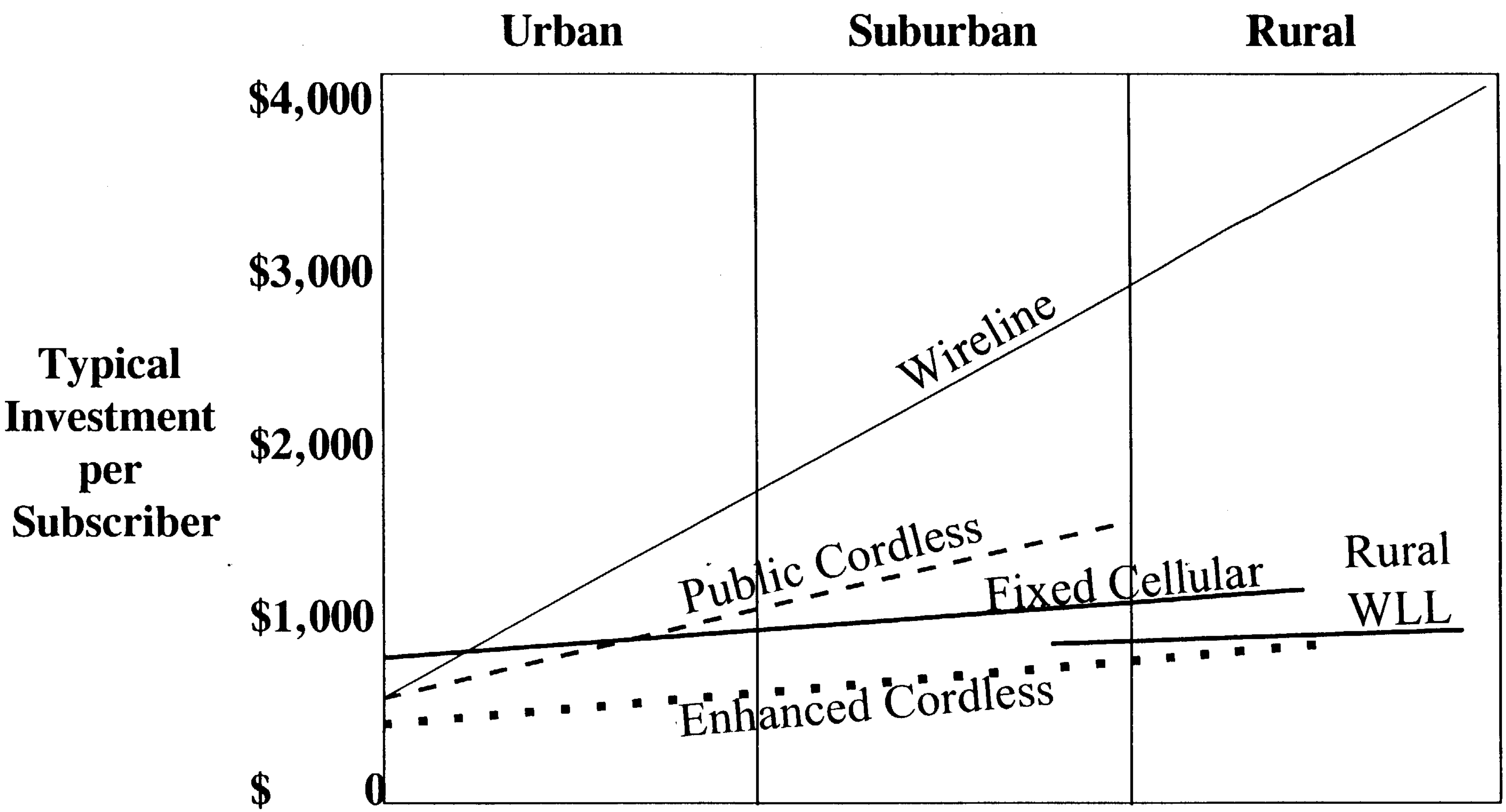
Wireless Telephony Alternatives
Mass Market Technologies

- Fixed Cellular (i.e., AMPS, TDMA, CDMA)
  - An overlay to the public network
  - Optimized for high-speed mobility
  - Complex planning and implementation
  - Premium cost, quality issues (8-13 kbps voice encoding)
  - Dominated by a few large suppliers
- Fixed Cordless (i.e., DECT, PHS, PACS)
  - An extension to PSTN
  - No radio planning (self-organizing)
  - Low power, coverage limitations
  - Low cost, high quality (32 or 64 kbps voice encoding)

Wireless Telephony Alternatives
True WLL Solutions

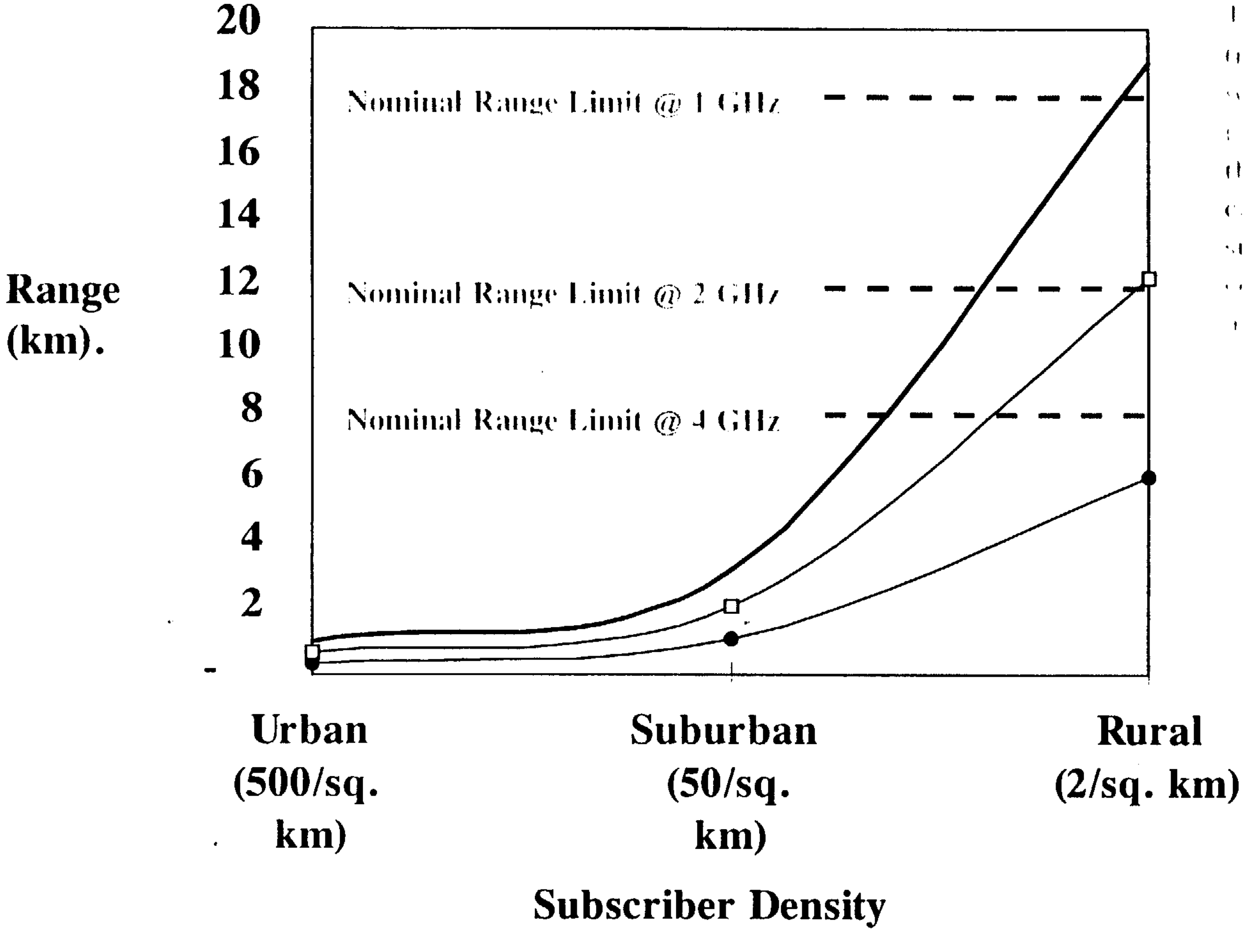
- Proprietary Systems (i.e., B-CDMA)
  - Wide array of technologies, fragmented market and spectrum allocations
  - Generally aimed at high-end of the market, incorporating 32-64 kbps voice and high-speed Internet
- Enhanced Cordless (i.e., long-range/hi-cap PHS)
  - Retains the cost and quality advantages of cordless, but with greater coverage (more suitable for rural areas)
  - Incorporates newer, more efficient technologies, i.e., smart antennas, IP protocol, etc.
  - Protocol modifications allow better transparency to central office- and Internet-based services

Wireless Telephony Alternatives
Price Effectiveness



Wireless Telephony Alternatives

Coverage - Nominal vs. Busy Hour



The graph illustrates the coverage (range from base station) within which busy hour traffic subscriber usage will saturate the base station's available capacity, based on the given subscriber densities. This is considered the effective range of a base station.

The overlaid dotted lines illustrate the maximum range, based on radio propagation at selected frequencies.

Technological Developments
Key Wireless Telephony Enablers

- Public Cordless (time division duplex-based)
  - Wireless 32 kbps (ADPCM) encoding (high quality voice)
  - Dynamic channel allocation (no frequency planning)
  - High-speed packet protocol for Internet access
- Network Interfaces (direct PSTN interconnection)
  - Digital interfaces (TR303/V5.2) reduce costs
  - Class 5 service transparency
- Spectrum Enhancements (increased coverage, capacity and reliability)
  - Smart antennas
  - Superconducting filters

Technological Developments

The Spectral Efficiency Bottleneck

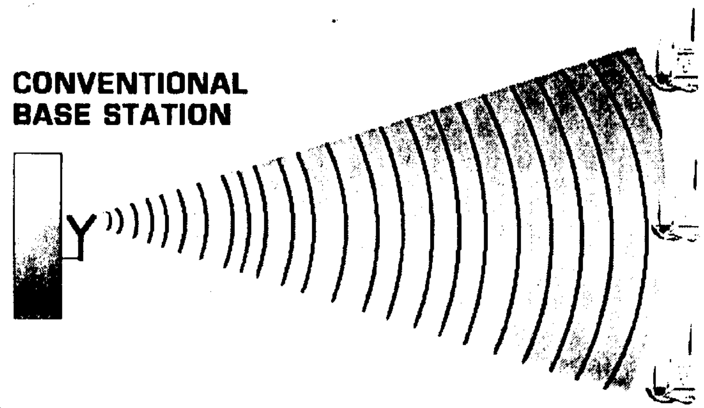
Today's Principal Spectral Inefficiency

omnidirectional/sectorized radiation and reception

Why?

only a tiny fraction of radiated power on uplink or downlink is available to the receiver

the rest - the vast majority - becomes interference for other co-channel users



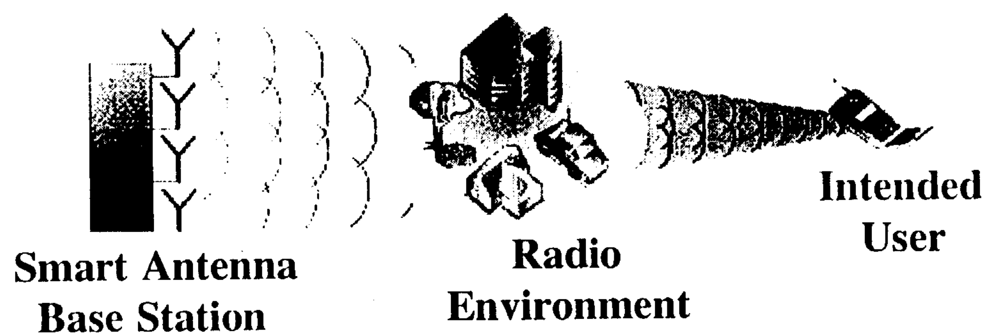
Technological Developments
The Spectral Efficiency Bottleneck

- Quest For Spectral Efficiency Has Focused on Time/Frequency Processing
  - modulation formats
  - channel and source coding
  - access methods
- (Good) Current Practice Is Near Theoretical Limits
  - all significant capacity gains from these areas have been realized already

Technological Developments

Smart Antennas

- Basic Idea
  - combine multiple antennas and modern signal processing techniques to instantaneously adapt the transmission and reception patterns of the base station to the radio environment, users and interferers
- Smart Antennas Are Spatial Processing Systems
  - can be applied to any air interface
  - significantly increase capacity and spectral efficiency
  - implementations in use worldwide today



Technological Developments

Smart Antennas

- Determinants of Performance
  - environmental complexity: rural is friendliest
  - degree of mobility: fixed is ideal
  - duplexing method: frequency division (FDD) vs. time division duplexing (TDD): TDD gains are higher

Application	Capacity Increase	Deployments
Enhanced Cordless WLL (TDD)	20 x	1996-present
Pedestrian Cordless PHS (TDD)	5 x	1996-present
Mobile Cellular AMPS, GSM (FDD)	>2 x	1993-present

Technological Developments
Smart Antenna Attributes

- Enhanced service quality and reliability
- Expanded coverage
- Greater capacity and higher data throughput
- Transparent to all wireless standards
- Low cost per subscriber
  - less radio spectrum required
  - fewer base stations
  - enables low-power, lower-cost subscriber equipment

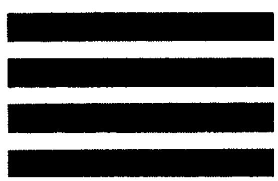
Technological Developments
Conventional Wireless Divides Spectrum

Freq-
uency **Radio Spectrum**

Time

FDMA

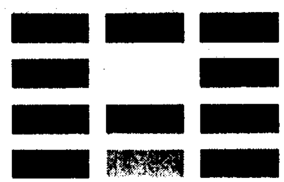
Freq-
uency



Time

TDMA

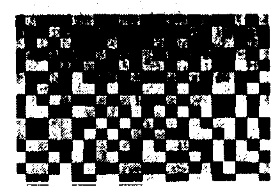
Freq-
uency



Time

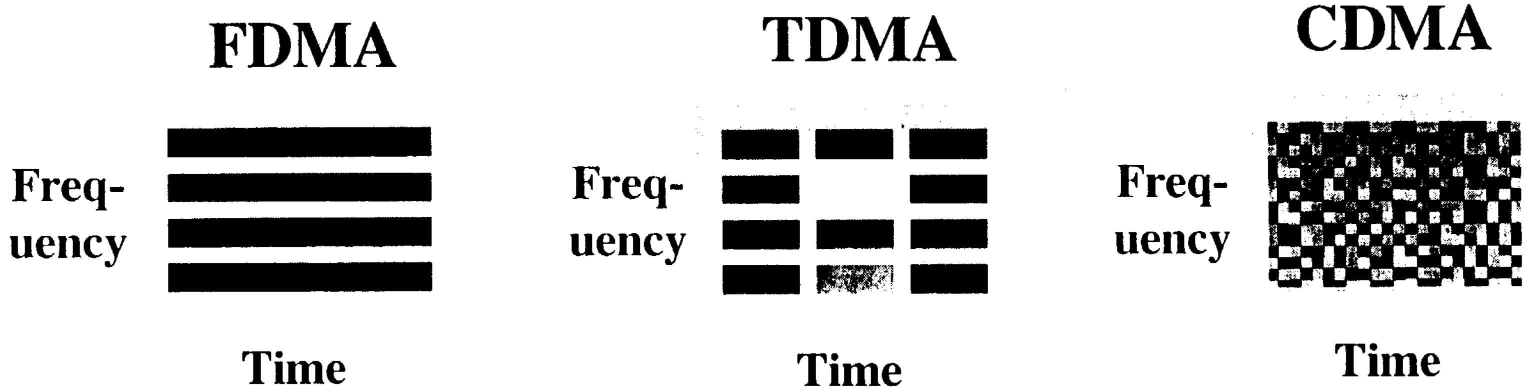
CDMA

Freq-
uency

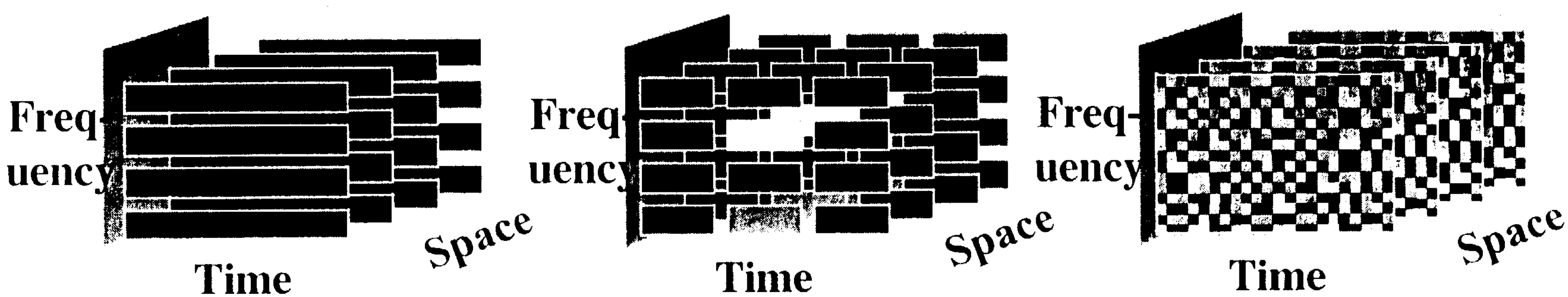


Time

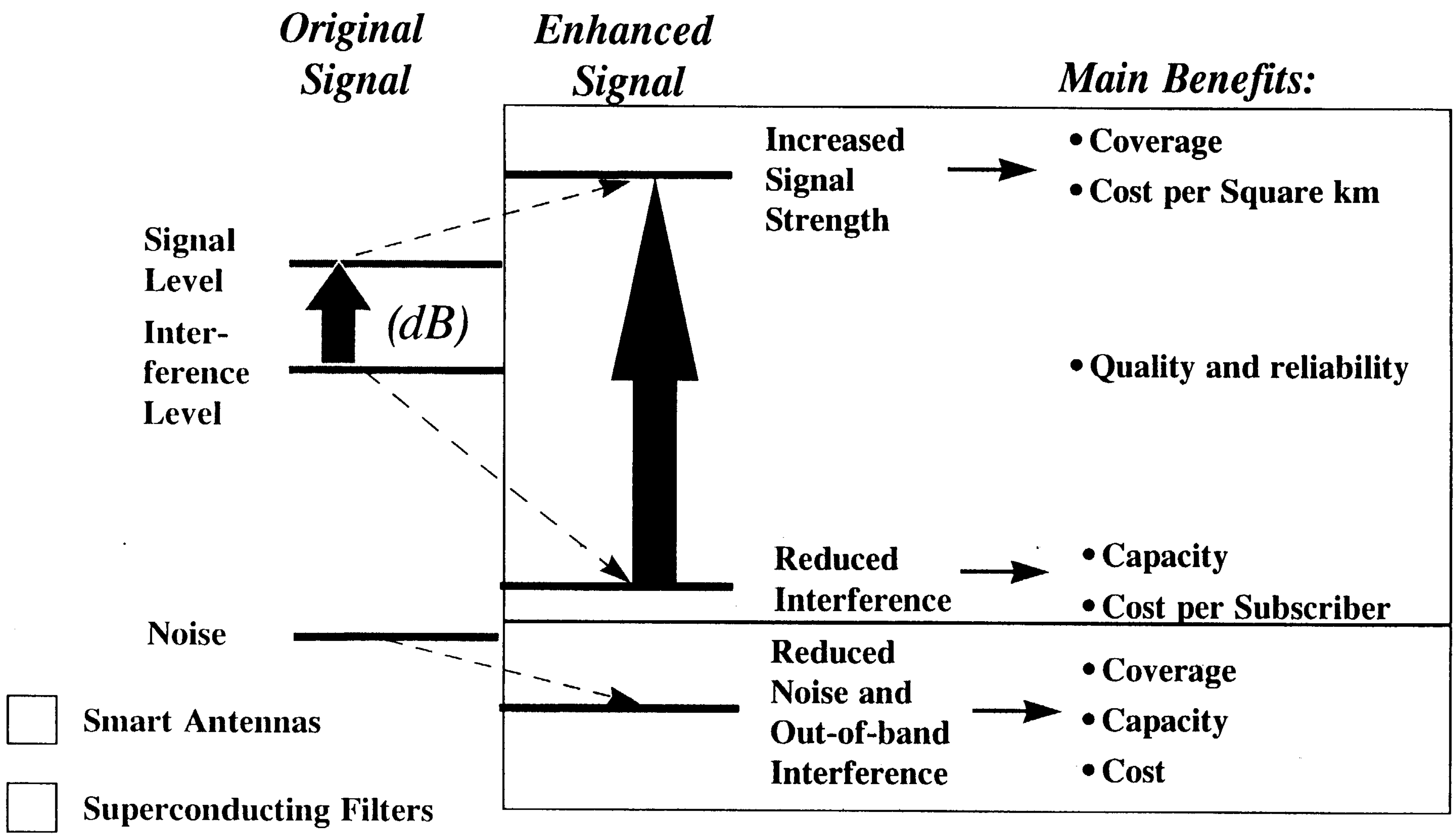
Technological Developments
Smart Antennas Multiply Spectrum



Spatial Channels



Enhanced Signal Quality



Technological Developments

FDD (i.e., cellular) vs. TDD (i.e., cordless)

	Advantages	Disadvantages
FDD	No need for synchronized network Suited to high-power applications Suited to extended range at < 1 GHz	Requires fragmented allocations More challenging for Smart Antennas Relatively hard to support asymmetry Expensive for small duplex distances
TDD	Operates in isolated allocations Well suited for Smart Antennas Cost-reduced user terminals Simple to support asymmetry	Requires synchronized network 50% duty cycle for radio electronics

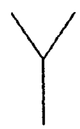
- Neither is fundamentally more efficient
- TDD is better suited for
  - smart antennas
  - asymmetric data services (Internet)

Technological Developments

Smart Antenna Power Efficiency

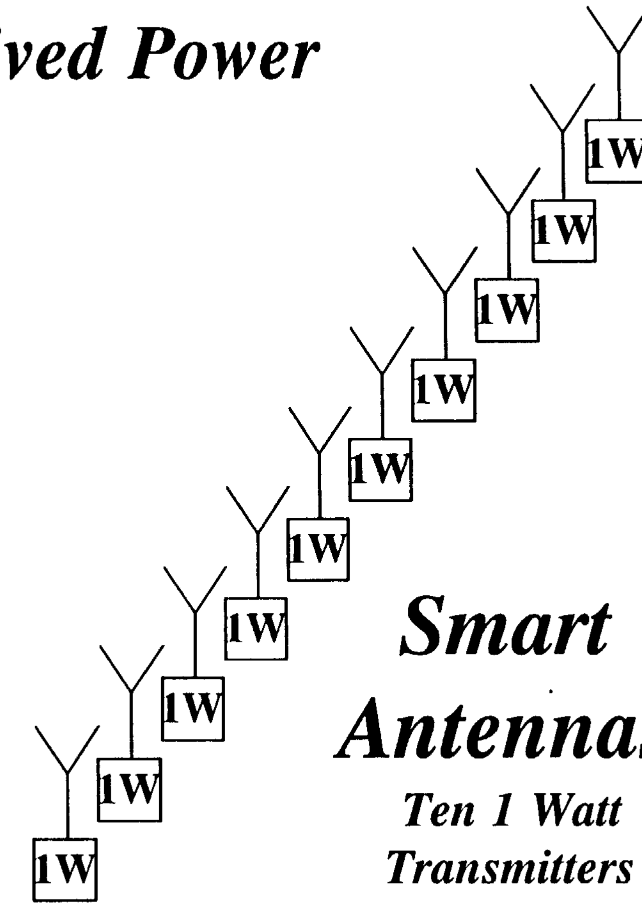
Same Received Power

Conventional



100 W

One 100 Watt transmitter has higher total power consumption and total cost



Smart Antennas

Ten 1 Watt Transmitters

Technological Developments
Smart Antennas and Internet Access

- Wireless Support for Packet Data More Difficult than for Voice!
  - Higher instantaneous bandwidth per user
  - More stringent data quality requirements
  - More dynamic and unpredictable interference
- Implications
  - Conventional systems will have poorer frequency reuse as compared with similar data rates for voice
  - Interference mitigation is most critical
  - Smart antennas will be indispensable for supporting Internet access

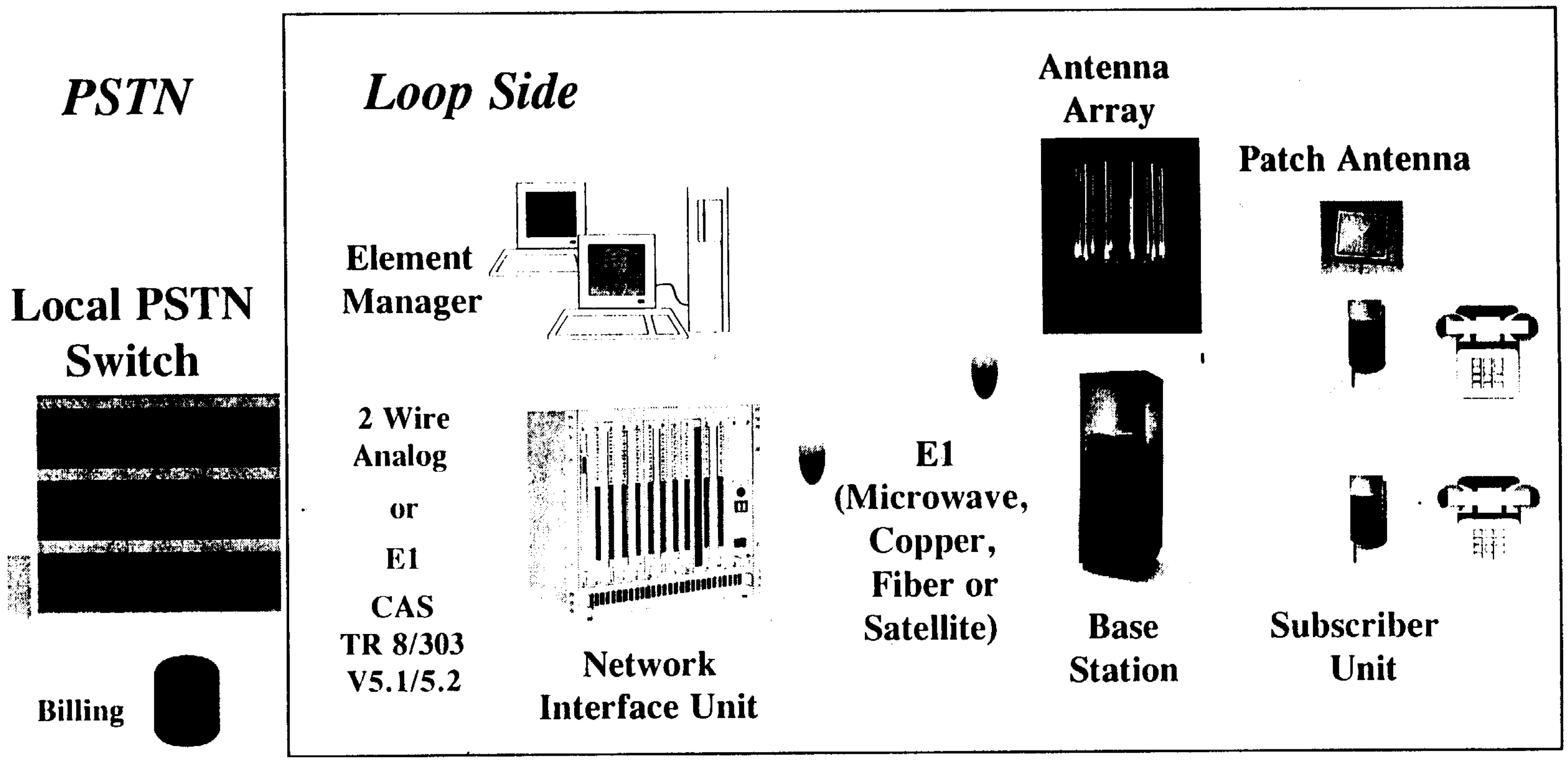
Technological Developments

PHS/Smart Antenna Case History

- **The Market**
  - PHS is a 1.9 GHz public cordless service and a leading alternative to having a second line in the home in Japan
  - Price is comparable to payphone call (< $0.10 per minute)
  - 7 million PHS subscribers in 2 years from launch
- **DDI Pocket Telephone, Inc.**
  - First wireless operator to widely deploy smart antennas
  - Serves 55% of the market (and 70% of the traffic) among 3 operators, with one-seventh the number of base stations
  - Became profitable in 2 years, 3 months from launch
  - 32 kbps data service now accounts for >20% of traffic and is fastest-growing segment (64 kbps data available Q2'99)

WLL Solutions
System Architecture

Enhanced Cordless WLL (employing smart antennas)



WLL Solutions
Technology Description

- Base station (with smart 12-antenna array), fixed subscriber unit, network interface unit and element manager
- Frequency band: 1880-1920 MHz (Re-tunable)
- Access method: TDMA (300 KHz spacing, 8 timeslots/carrier)
- Duplex method: Time division duplex (TDD)
- Voice encoding: 32 kbps ADPCM
- Modulation: p/4 DQPSK
- Telephony-transparent on switch and CPE sides
- Transparently supports PSTN class 5 services
- Voiceband data and G.3 fax supported
- Data option for 64 kbps clear channel
- Single, multiline and payphone subscriber units

WLL Solutions
Other Technology Enhancements

- Bi-directional Closed Loop Power Control
- Signaling optimizations for fast call setup
- Over air software download and OMC
- Timing advance and equalization

WLL Solutions

Deployability

- Dynamic channel allocation
  - no frequency planning
  - self-synchronizes and self-organizes system resources
- Smart Antennas
  - adapt to interference, changes in the environment, etc.
  - no special installation, matching or precision antenna engineering (or re-engineering) required
- "Software" Radio
  - comprehensive remote monitoring, diagnostics, etc.
  - remotely software upgradeable

WLL Solutions
Rural Infrastructure/Implementation Issues

- Network backbone alternatives
  - microwave
  - satellite
- Shelters (to control environmental and security)
  - existing structures, where feasible
  - new/dedicated, where necessary
- Alternative Power (for autonomy or backup)
  - solar
  - wind

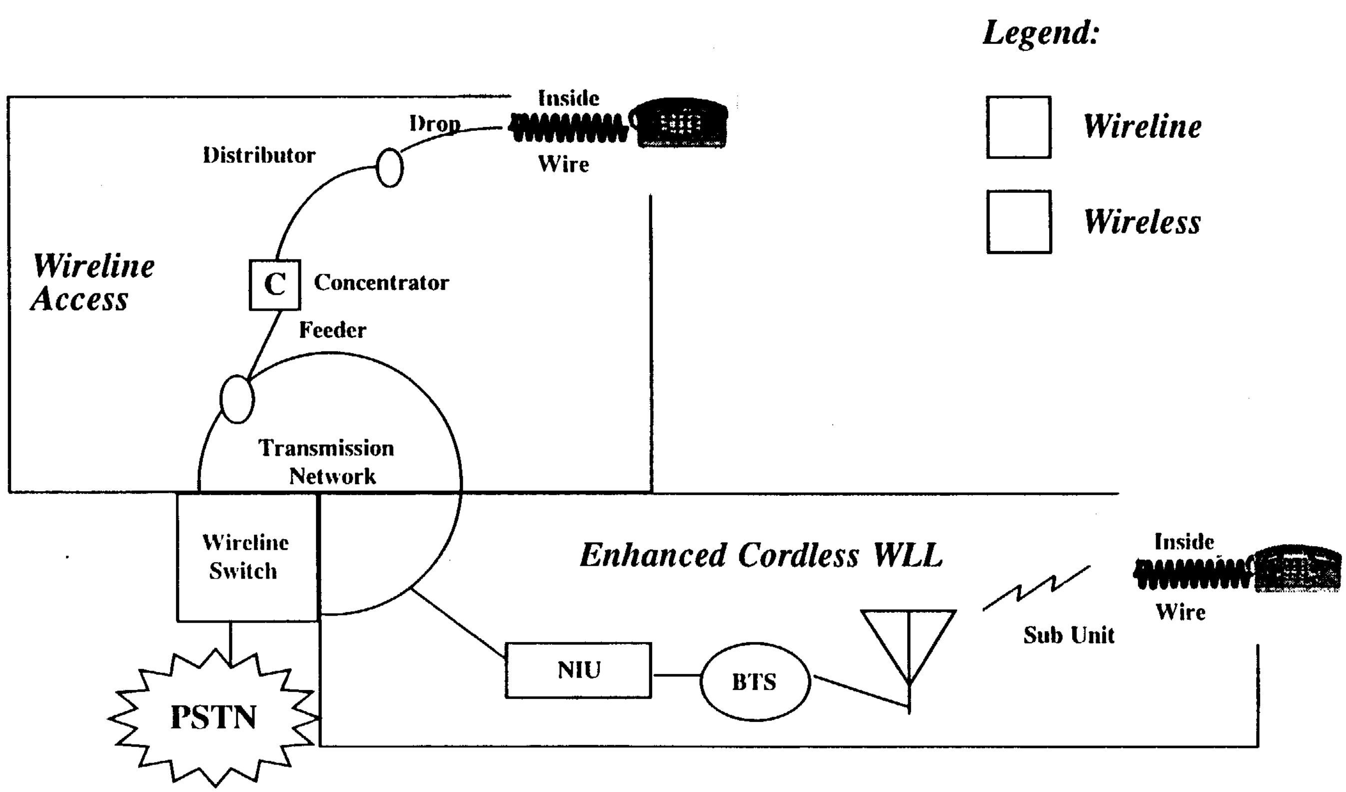
Economics
Brazil Study - Overview

- Turnkey installation from subscriber phone to the central office (no switch)

Wireline Technology	Twisted Pair
Wireless Technology	Enhanced Cordless WLL
Population of Service Area (000)	17,000 (mixed urban to rural)
Growth Rate	0.5%
Penetration (Total Lines/Total Population)	
- Year 1	24.5%
- Year 10	41%
Tariff	
- Monthly Fixed Costs	$ 13.00
- Price/Minute	$ 0.06
Minutes of Use (MOU) per subscriber	350 per month
Network Deployment Time	4 Years WLL, 6 Years Wireline

Economics

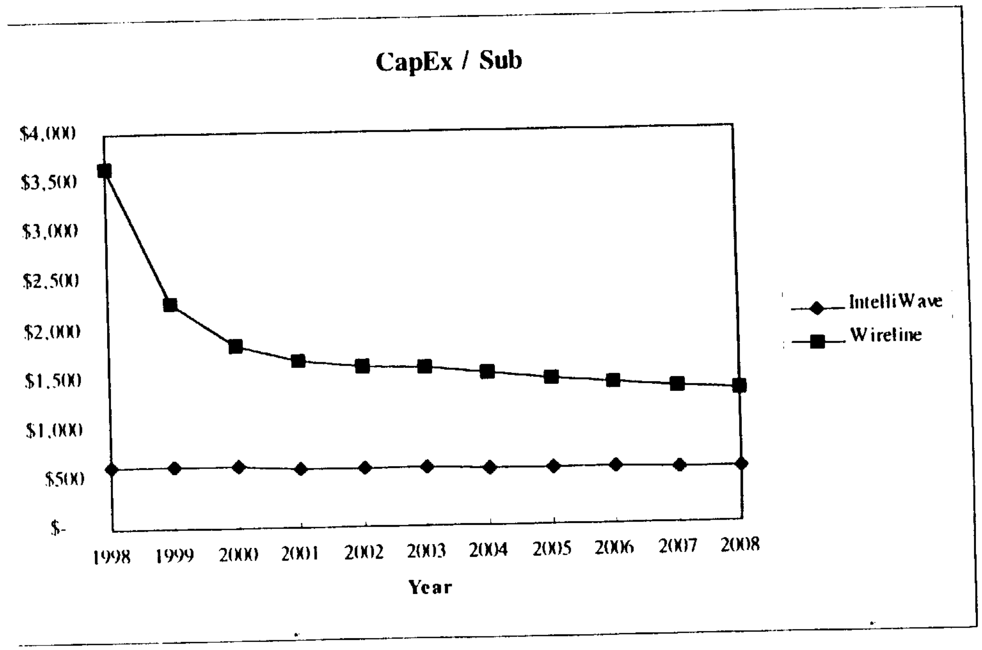
Brazil Study - Network Reference Diagram



ArrayComm Proprietary and Confidential

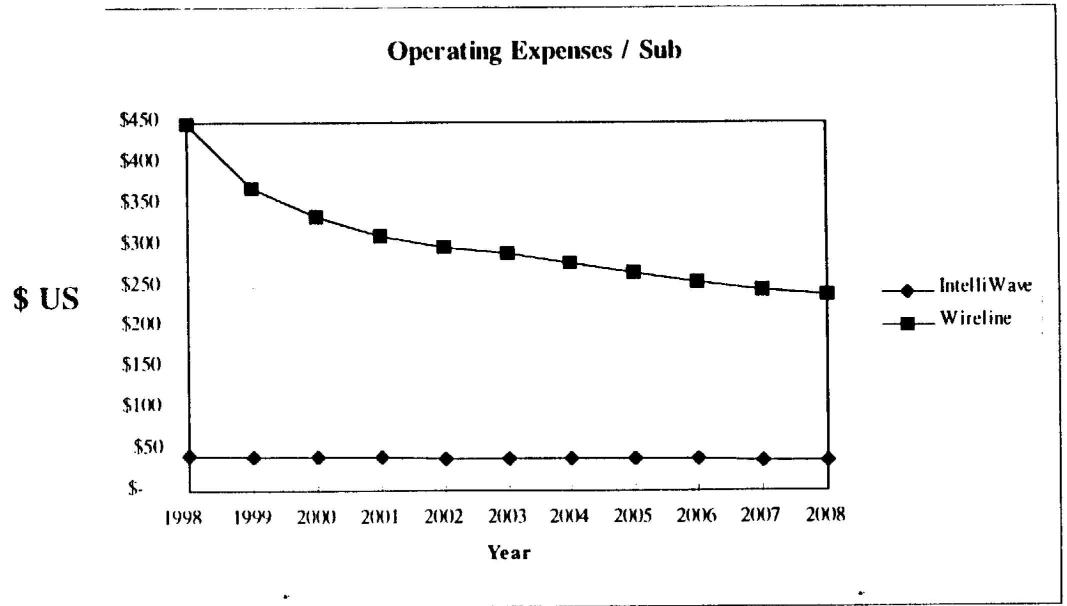
Economics
Brazil Study - Capital Expenditure / Sub

$ US



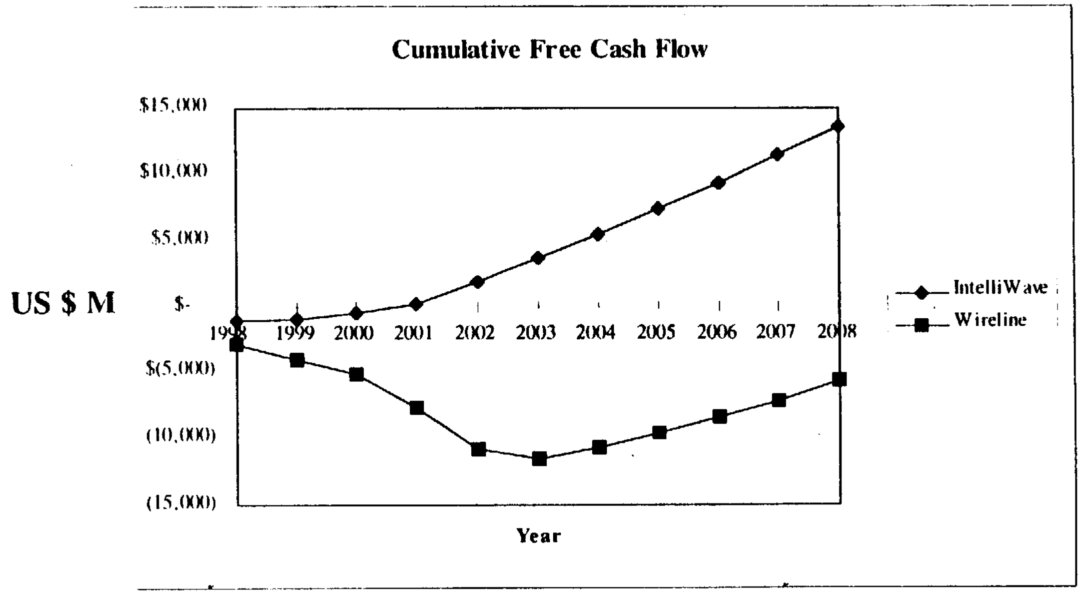
WLL technology not only requires less network investment than a wireline network, but also scales with subscriber growth, reducing financial risk.

Economics
Brazil Study - Operating Expense / Subscriber



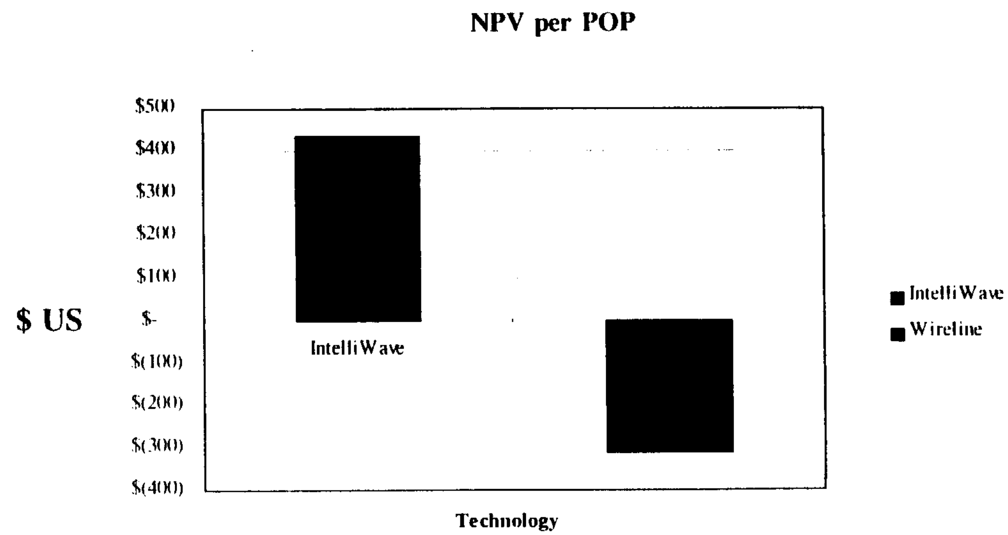
Network operating expenses are five times as much for a wireline network. This greatly reduces working capital needs, resulting in greater valuation.

Economics
Brazil Study - Peak Funding



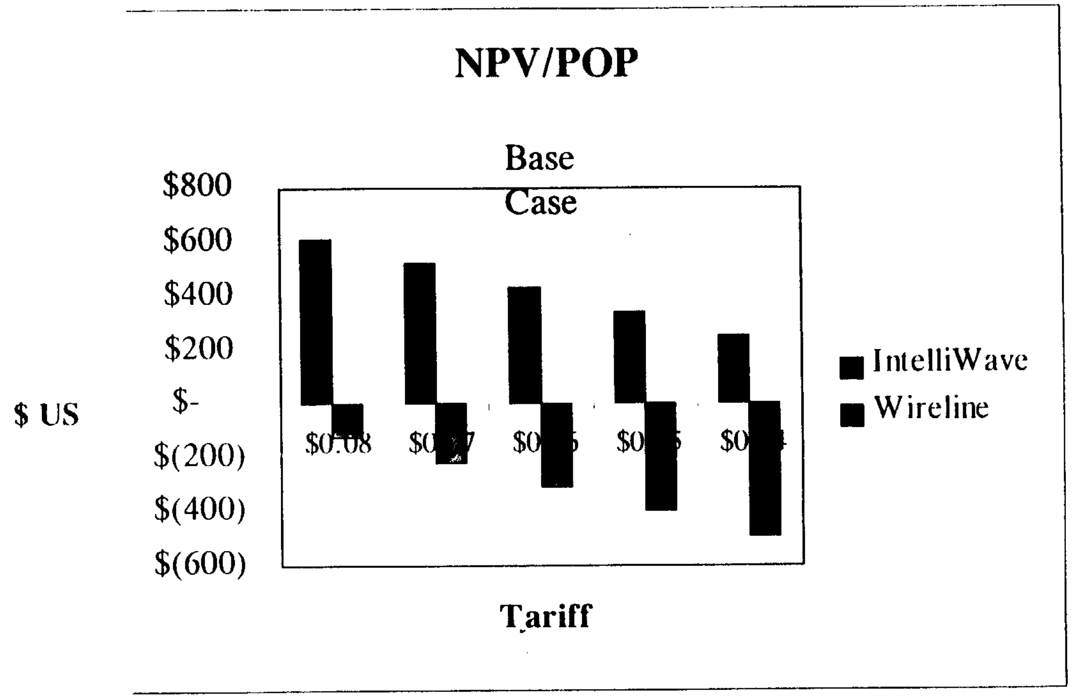
The operator recoups investments by Year 3 in the WLL case while this would not occur in the first 10 year in the wireline scenario.

Economics
Brazil Study - Net Present Value (NPV) / POP



The Enhanced Cordless WLL network would generate much greater value than the wireline network. ($433 NPV vs. $ -241 NPV/POP)

Economics
Brazil Study - Tariff Sensitivity



While the wireline network is a poor investment if tariff forecasts are not achieved, the Enhanced Cordless system still provides high value.

Economics
Brazil Study - Summary

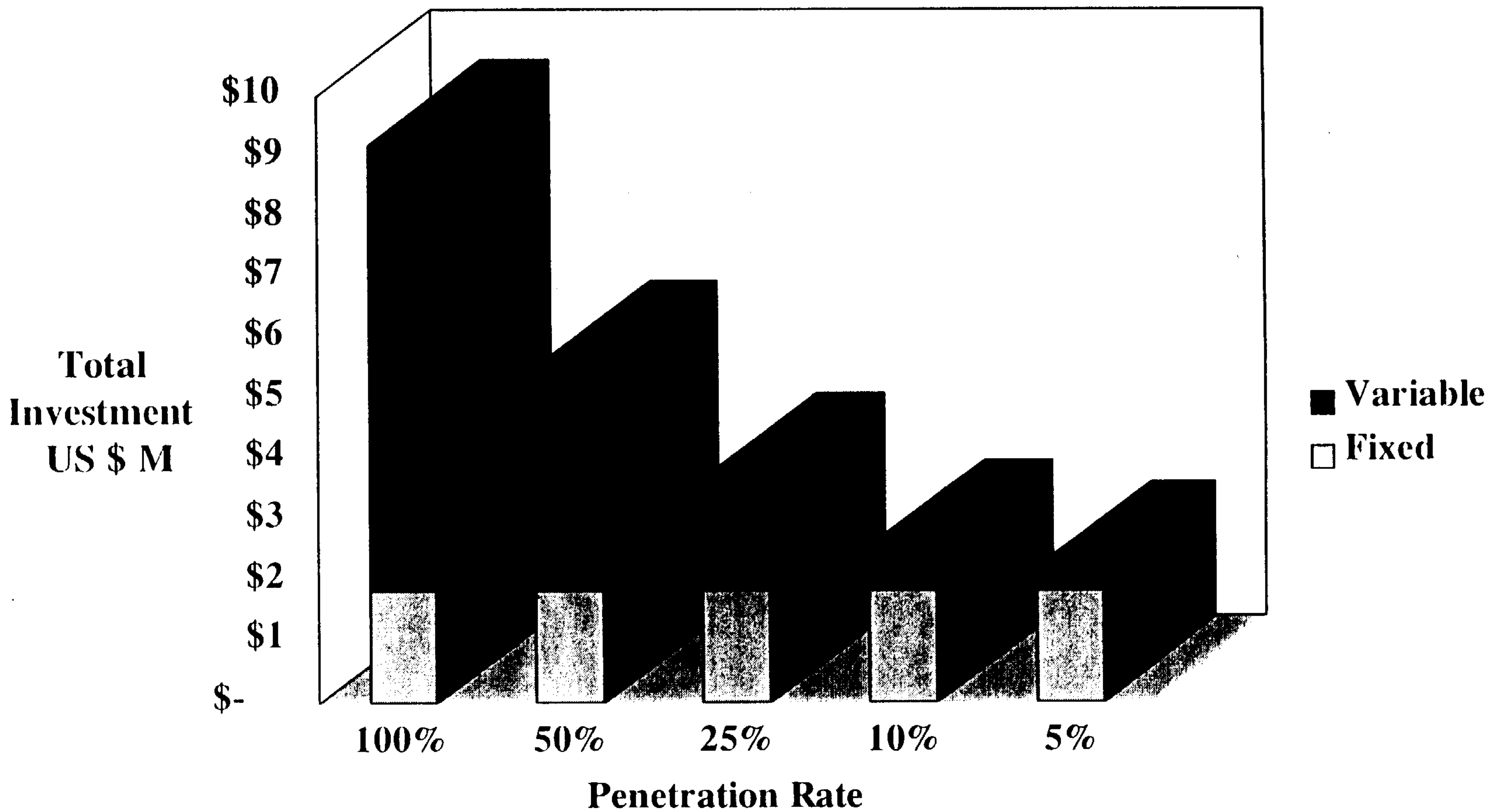
	Wireless	Wireline
CapEx/Sub (Year 10)	$ 560	$ 1,345
OpEx/Sub (Year 10)	$ 37	$ 240
Peak Funding (millions)	$ 1,169	$ 11,584
Payback Period	Year 3	Year 10 +
IRR	65%	5%
NPV/POP	$ 433	$ (309)

The analysis clearly shows the superior economic value for an operator from deploying an Enhanced cordless network over a standard wireline network.

Economics
U.S. Rural Case

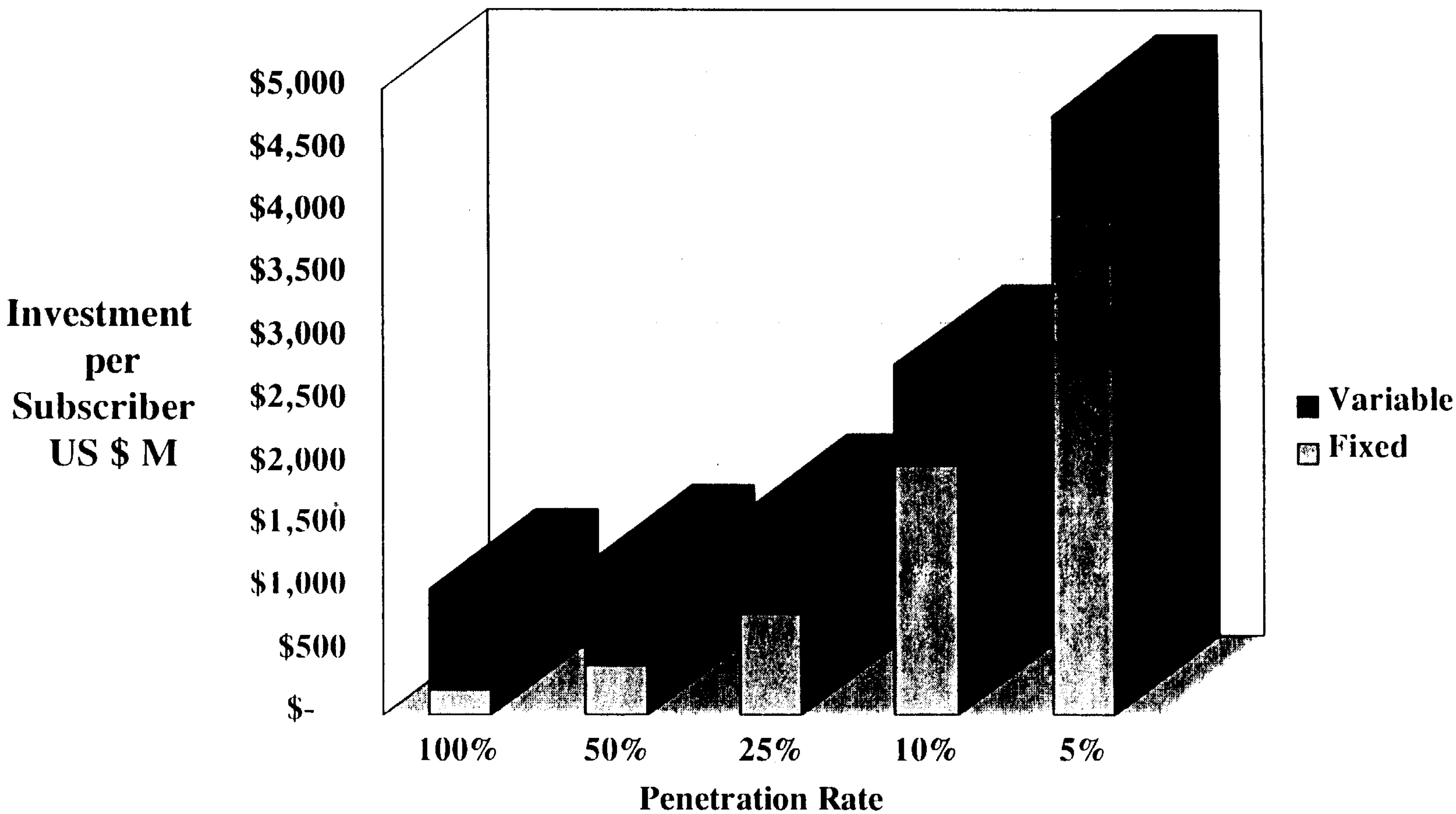
- Population density:20 per sq. km
- Minutes of use per subscriber: 1,000 per month
- Wireline
  - twisted pair or cable telephony new build
  - Fixed costs: investment per inhabitant passed (feeder and distribution plant installed)
  - Variable costs: investment per customer connected (last mile drop wire and loop electronics installed)
- Wireless
  - WLL technology based on enhanced public cordless
  - Base station range: 12.1 km
  - Fixed subscriber terminal AC powered with battery backup

Economics
U.S. Rural Case- Wireline Telephony

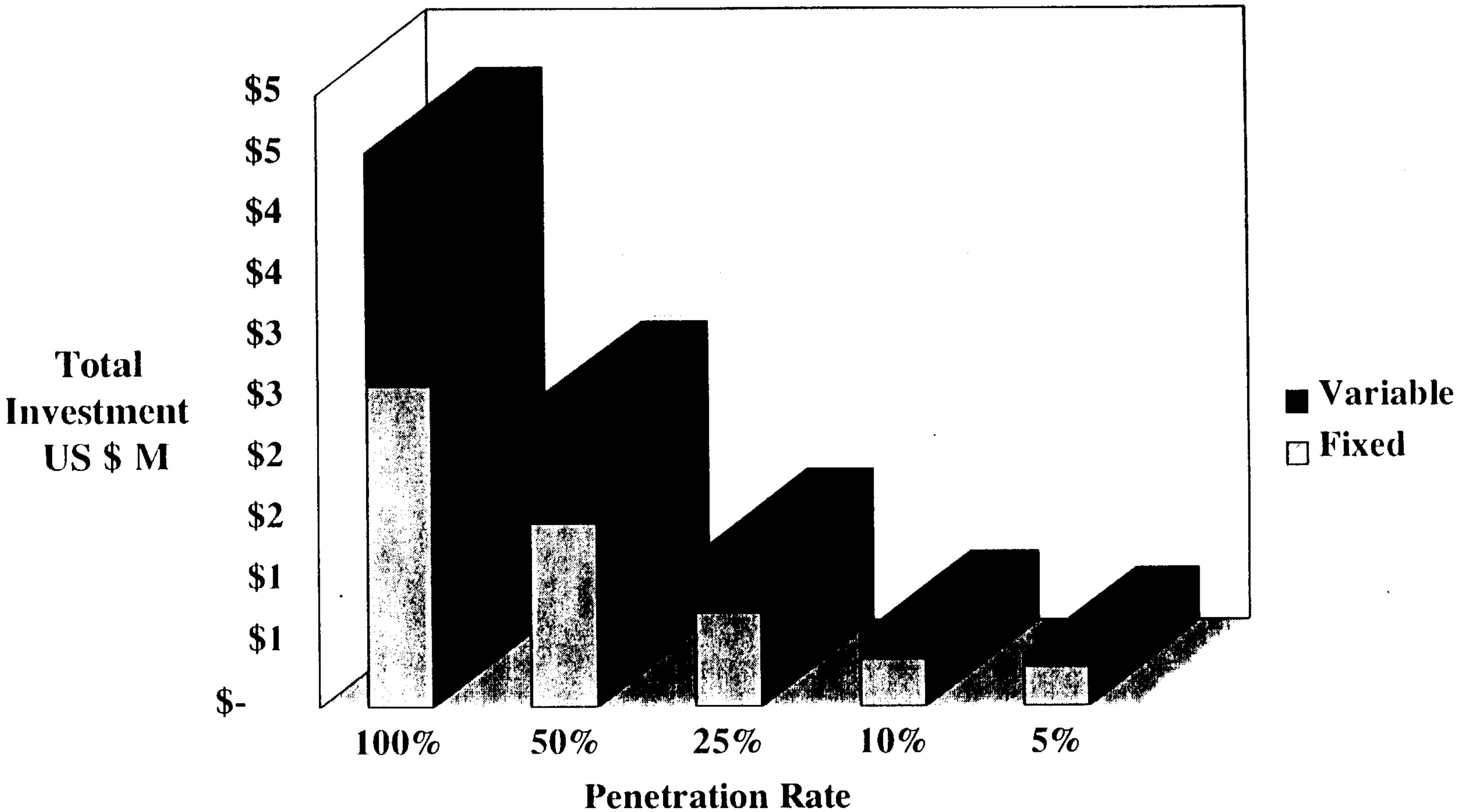


Economics

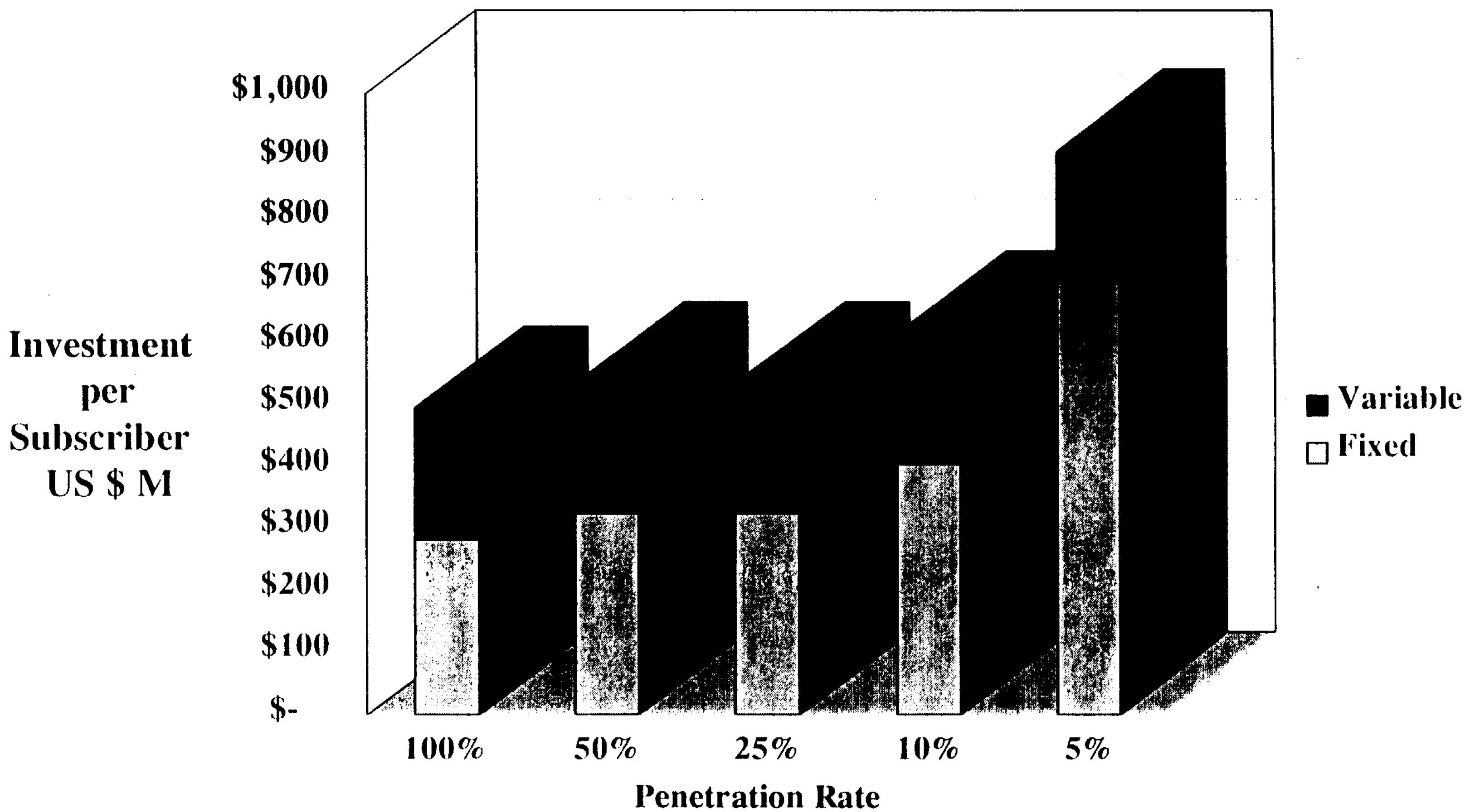
U.S. Rural Case- Wireline Telephony



Economics
U.S. Rural Case - Enhanced Cordless WLL

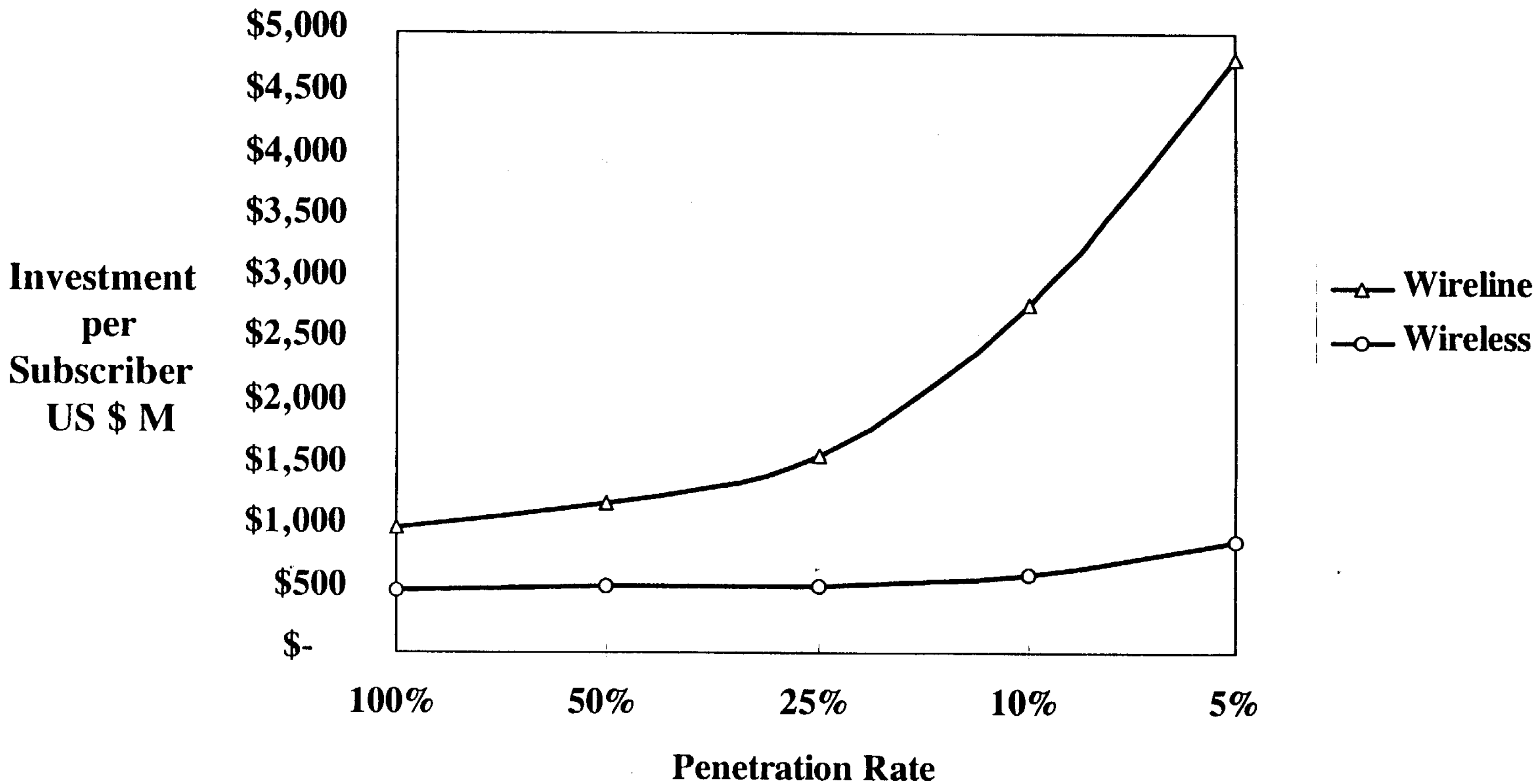


Economics
U.S. Rural Case - Enhanced Cordless WLL



Economics

U.S. Rural Case -(Sensitivity to Penetration Rates)



Economics
U.S. Rural Case - Summary

- Approximate investment per "home" passed
  - Wired: $800
  - WLL: $ 30
- Payback on capital investment@ 10% penetration

	$ 30/mo.	**$ 20/mo.** ← **Service Price**
Wired:	8 years	12 years
WLL:	2 years	3 years

- *Even in urban and suburban areas, McKinsey & Co. in their 1998 report, <u>Breaking the Access Bottleneck</u>, cites the following breakeven (net profit) penetration rates:*
  - *Twisted pair or Coax new build:* *30%*
  - *Fixed wireless new build:* *10%*

Economics
Summary

- Wide coverage (fewer sites for coverage)
- High capacity (fewer sites, less spectrum required)
- Faster deployment
  - Fewer sites
  - No frequency planning
  - Minimal antenna engineering
- Consistently high voice quality and data rates
- Low investment per subscriber
- Lower lifecycle costs
  - Less rent, utilities, maintenance expense
  - Less re-engineering for growth
  - Software upgradeability

Regulatory Policy Issues
Technology Implications

- Smart antennas reduce the cost of providing wireless services (cap-ex and op-ex)
  - lowering entry barrier to new operators
  - making possible all-inclusive, affordable services with inexpensive terminals
- Smart antennas enable useful applications in even limited allocations
  - especially important for certain new allocations below 3 GHz
  - gains are most significant with TDD

Regulatory Policy Issues
Key Themes

- Inclusion
  - Indian telecommunications should be supported but not insulated from national services & technology trends
  - Promote access to larger economies of scale in the industry
  - Low-cost Internet access should to be part of the economic equation and business/educational stimulus
- Opportunity and Choice
  - No one solution or technology will serve all needs
  - Competition will produce solutions and reduce cost
  - Reduce regulatory barriers (i.e., no auction)
  - Real choices will allow Indians to leapfrog technology & cost barriers

Regulatory Policy Issues

Frequency Pairings

- Offer unpaired frequencies
- Avoid adjacent band coexistence issues (especially with FDD systems) similar to WCS
- Offsets FDD dominance in 1 - 3 GHz bands
- Promotes new technologies, enables differentiation among challengers
- Fosters competition and innovation at all industry levels

Regulatory Policy Issues
Allocations below 3 GHz

- Most desirable band for individual user access
  - favorable propagation with respect to scattering, shadowing, building penetration
  - attractive form factor: component size scales inversely with frequency
- Spectrally efficient technologies are especially critical here
  - typical spectrum allocations range between 5 - 30 MHz

Regulatory Policy Issues
Spectrum Licensing

- 1-3 GHz band is preferred (the lower, the better), noting that:
  - 3650-3700 (ET docket No. 98-237) is not the answer, due to coverage limitations
  - 2110-2150 is part of the paired IMT-2000/UMTS spectrum, and will likely be paired with PCS bands
- Free up 1 National and 1 large regional spectrum block (e.g., REAG per WCS rules)
- Offer 10 MHz of spectrum per license

Regulatory Policy Issues
Spectrum Licensing

- No auction (no up front license fee), but require minimum service commitments from license holder to Indian communities
- In the case of regional licenses, allow license holders to have preference (i.e., first right of refusal) on acquisition of license outside of Indian lands
- Allow license holders any use of spectrum outside Indian lands

Regulatory Policy Issues
Spectrum Licensing

- Lottery, with technical/commercial prequalification
- Tender, based on technical and commercial merit
- Offer Indian participation in the adjudication of lottery application/tenders
- Offer Indian participation in the license itself

Conclusions
Consistency with Chairman Kennard's Principles

- Community
  - promote affordable services for all citizens
- Common Sense
  - regulate only when necessary
  - encourage spectral efficiency
- Competition
  - reduce entry barriers for new operators